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APPLICATION FOR LETTERS PATENT

for

**POLARIZED RETICLE, PHOTOLITHOGRAPHY SYSTEM, AND METHOD OF
FORMING A PATTERN USING A POLARIZED RETICLE IN CONJUNCTION
WITH POLARIZED LIGHT**

Inventor:

Jeff Mackey

Applicant's Attorneys:

Marcus S. Simon

Registration No. 50,258

Joseph A. Walkowski

Registration No. 28,765

TRASKBRITT

P.O. Box 2550

Salt Lake City, Utah 84110

(801) 532-1922

TITLE OF THE INVENTION

POLARIZED RETICLE, PHOTOLITHOGRAPHY SYSTEM, AND METHOD OF FORMING A PATTERN USING A POLARIZED RETICLE IN CONJUNCTION WITH POLARIZED LIGHT

BACKGROUND OF THE INVENTION

[0001] Field of the Invention: The present invention relates to the design of reticles used in photolithographic processing of substrates such as semiconductor wafers. More specifically, the present invention relates to reticles having a layer of a polarized material and methods of exposing the reticle using polarized light to produce a high resolution image on a photoresist.

[0002] State of the Art: Semiconductor devices including integrated circuitry, such as memory dice, are mass produced by fabricating hundreds or even billions of circuit patterns on a single semiconductor wafer or other bulk semiconductor substrate using photolithography in combination with various other processes. In order to increase the number of memory cells on semiconductor memory devices for a given surface area, it is important to accurately control the optical resolution of the images produced during photolithography. These images are used to define structural features on a semiconductor substrate to fabricate the integrated circuitry of such semiconductor memory devices.

[0003] Photolithography is a process in which a pattern is delineated in a layer of material, such as a photoresist, sensitive to photons, electrons, or ions. In photolithography, an object containing a pattern (e.g., reticle or mask) is exposed to incident light. The image from the reticle or mask is projected onto a photoresist that covers a semiconductor wafer or other substrate. The photolithographic process typically involves exposing and developing the photoresist multiple times with deposition, etch, and/or implant steps in between. At a given step, the photoresist is selectively exposed to photons, electrons, or ions, then developed to remove one of either the exposed or unexposed portions of photoresist, depending on whether a positive or negative photoresist is employed. A complex device typically requires multiple exposure and development steps.

[0004] There are three predominant conventional photolithography methods of optically transferring a pattern on a reticle or mask to a photoresist that is coated on a substrate. These methods are contact printing, proximity printing, and projection printing.

Currently, projection printing is the most frequently used type of photolithography system. Referring to FIG. 1, a conventional photolithography system used in projection printing is shown. Photolithography system 100 includes illumination controller 102 operably coupled to illumination source 104 for producing light. Illumination source 104 typically includes a mirror, a lamp, a laser, a light filter, and/or a condenser lens system. In the exposing system shown in FIG. 1, illumination source 104 irradiates reticle 106 having the desired pattern to be projected onto photoresist 110. Projection lens 108, which may include a complex set of lenses and/or mirrors, focuses the image from reticle 106 onto photoresist 110. Photoresist 110 is developed and substrate 112 is subsequently processed as by etching to form the desired structures and photoresist 110 is then removed.

[0005] A major problem in the manufacture of memory dice and other semiconductor devices using photolithography is that the periphery region and the array region of the reticle have their largest process windows under different illumination conditions. This problem is particularly exacerbated when the feature sizes to be formed on the photoresist are small, such as around on the order of one-half of the wavelength of the light source used or less. A typical reticle pattern of reticle 200 comprises an array region 204 and a peripheral region 202 as shown in FIG. 2A. FIG. 2B illustrates a view of a single array region 204 surrounded by the peripheral region 202. Again referring to FIGs. 2A and 2B, the array region 204 and the peripheral region 202 of reticle 200 have different patterns. For instance, the array region 204 may contain a periodic pattern with particular dimensions and the peripheral region 202 may contain a different pattern having a smaller or larger dimension, possibly a different periodic pattern, or even a non-periodic pattern.

[0006] In conventional photolithography, the reticle having the peripheral pattern and the array pattern are exposed to the illumination source at the same time. However, the optimal illumination conditions for the array region and the peripheral region are not identical. The term “illumination condition” as used herein should be understood to include the distribution of angles of light used to irradiate the reticle and the total intensities of the light in those angles. A relatively tightly spaced pattern characteristic of the array region typically requires illumination by a circular annulus of light at a fairly steep incident angle. A relatively sparse pattern characteristic of the peripheral region typically has its optimal illumination conditions when using a single plane wave of incident light. Thus, each region

of the reticle has particular illumination conditions such as depth of focus, dose and angle of incident light, among others, which have different optimal values for the array and the peripheral region. Therefore, if the illumination conditions are optimized for the array region, the illumination conditions for the peripheral region are sub-optimal and vice versa. U.S. Patent 5,245,470 to Keum attempts to overcome some of the problems with producing patterns using photolithography.

[0007] A possible solution to this problem is to use more than one reticle, as is commonly known in the art, and sometimes used in the fabrication of semiconductor devices. However, the use of dual reticles suffers from two main deficiencies. First, it adds the additional cost of manufacturing or buying a second reticle. Second, the use of more than one reticle decreases the process throughput by requiring the changing out of the first reticle for the second reticle and often times necessitating re-calibration of the photolithography system. Third, the use of more than one reticle also causes problems with overlay errors between the two reticles.

[0008] Accordingly, in order to improve the quality of patterns transferred to photoresists using photolithography, a need exists for a single reticle photolithography system suitable for exposing regions of the reticle having distinct patterns under different illumination conditions optimal for each respective region.

BRIEF SUMMARY OF THE INVENTION

[0009] The present invention, in a number of embodiments, includes polarized reticles, methods of manufacturing the polarized reticles, photolithography systems utilizing such polarized reticles, and methods of using the polarized reticles to produce a pattern image on a photoresist. By using the polarized reticles of the present invention, a single reticle having a plurality of patterned regions may be exposed to light under optimum illumination conditions for each particular region. The present invention may be used in photolithographic processing for fabrication of semiconductor devices, liquid crystal display elements, thin-film magnetic heads, reticles, and for many other applications that require accurate photolithographic imaging.

[0010] In one aspect of the present invention, a polarized reticle having at least one layer of a polarized material is disclosed. The polarized reticle includes at least one first

patterned region at least partially surrounded by at least one second patterned region, each region having different patterns defined thereon. A polarized material may be disposed over at least a portion of the first patterned region of the reticle and a polarized material may be disposed over at least a portion of the second patterned region. The polarization direction of the polarized material on the first patterned region is generally orthogonal to the polarization direction of the polarized material on the second patterned region. Methods of fabricating the polarized reticle of the present invention are also disclosed.

[0011] In another aspect of the present invention, a photolithography system is disclosed. The photolithography system includes an illumination controller operably coupled to an illumination source. An illumination source such as, for example, a laser may be used to irradiate linear polarized light. A movable half-wave polarizer may be disposed between a polarized reticle of the present invention and the illumination source. The movable half-wave polarizer is positioned and configured to alter the polarization direction of the light from the illumination source when the light from the illumination source is passed through it.

[0012] In another aspect of the present invention, a method of exposing a reticle to light is disclosed. A substrate having a photoresist is provided. A polarized reticle of the present invention is disposed between an illumination source and the substrate, wherein the polarized reticle includes at least one first patterned region at least partially surrounded by at least one second patterned region, a top side, and a backside. The top side of the polarized reticle may be exposed using linear polarized light from the illumination source. The linear polarized light may be filtered by the polarized reticle from exiting either the first patterned region or the second patterned region of the backside of the polarized reticle. After one region of the reticle is exposed producing a pattern on the photoresist, the other region of the reticle may subsequently be exposed. Utilizing the polarized reticles of the present invention enables each respective region of the polarized reticle to be exposed under their respective optimal illumination conditions. Thus, a single reticle may be used to expose multiple patterns using optimal illumination conditions for each respective pattern.

[0013] In yet another aspect of the invention, a method of exposing a reticle to light is disclosed. A substrate having a photoresist disposed thereon is provided. A polarized reticle of the present invention is disposed between an illumination source and the

photoresist on the substrate. The reticle includes a pattern thereon having at least one first patterned region at least partially surrounded by at least one second patterned region. The reticle may be irradiated with linear polarized light from the illumination source. A region of the pattern may be selectively projected onto the photoresist. The polarization direction of the linear polarized light irradiated from the illumination source may then be altered by approximately ninety degrees followed by selectively projecting the other region of the pattern onto the photoresist.

[0014] These features, advantages, and alternative aspects of the present invention will be apparent to those skilled in the art from a consideration of the following detailed description taken in combination with the accompanying drawings.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0015] In the drawings, which illustrate what is currently considered to be the best mode for carrying out the invention:

[0016] FIG. 1 illustrates a conventional photolithography system.

[0017] FIG. 2A is a plan view of a typical reticle used in the semiconductor fabrication industry including array and peripheral regions.

[0018] FIG. 2B is an enlarged plan view of a portion of the reticle shown in FIG. 2A.

[0019] FIG. 3A illustrates a plan view of the top surface of a polarized reticle according to the present invention.

[0020] FIG. 3B is an enlarged plan view of a portion of the polarized reticle shown in FIG. 3A.

[0021] FIG. 3C illustrates a sectional view of a polarized reticle of the present invention.

[0022] FIG. 4 illustrates an exemplary exposing system used in conjunction with the polarized reticle of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0023] The present invention, in a number of embodiments, includes polarized reticles, methods of manufacturing the polarized reticles, photolithography systems utilizing such polarized reticles, and methods of using the polarized reticles to produce a pattern image that may be used in the processing of substrates. The present invention may be used in photolithographic processing for fabrication of semiconductor devices, liquid crystal display elements, thin-film magnetic heads, reticles, and for many other applications that require accurate photolithographic imaging. The present invention may employ step-and-repeat or step-and-scan type projection printing, or other similar systems.

[0024] Referring to FIGs. 3A-3C, an exemplary polarized reticle 300 is shown. Polarized reticle 300 contains a reticle 301 having a pattern defined thereon. Reticle 301 may be formed from materials such as quartz or a borosilicate glass. Fabrication of reticle 301 may be effected using masking and etching techniques common to photolithography processing used in the semiconductor fabrication industry.

[0025] As illustrated in FIG. 3A, polarized reticle 300 may be comprised of a plurality of peripheral regions 302 and a plurality of array regions 304. Each array region 304 is generally surrounded by the peripheral region 302. The array region 304 contains a pattern different than a pattern of the peripheral region 302. The pattern contained within the array region 304 may, for example, have larger or smaller feature sizes, be a pattern having a different periodicity, or both, than the pattern contained within the peripheral region 302. The pattern contained within array region 304 may also be a non-periodic pattern that is different than the pattern contained within the peripheral region 302. The dimensions of the polarized reticle 300 may exhibit dimensions common to reticles used in the semiconductor fabrication industry, such as approximately 6 inches by approximately 6 inches. Referring to FIG. 3B, the width (W) of the peripheral region 302 may be approximately 1/10 of an inch. The array region 304 may have dimensions approximately $\frac{1}{2}$ (L_1) inches by 1 (L_2) inches with the array region 304 generally surrounded by the peripheral region 302. However, the above mentioned dimensions and pattern are merely illustrative and are not meant to limit the present invention. The present invention embraces any polarized reticle comprised of at least one first patterned region at least partially

surrounded by at least one second patterned region, wherein the first patterned region includes a pattern different from the pattern of the second patterned region.

[0026] Again referring to FIGs. 3B and 3C, a polarized material 308 is disposed over the peripheral region 302 to selectively coat the peripheral region 302 on reticle 301. A polarized material 310 is disposed over the array region 304 to selectively coat the array region 304 on reticle 301. Thus, the polarized material 308 and the polarized material 310 may respectively completely cover the peripheral region 302 and the array region 304. The polarization directions of the polarized material 308 and the polarized material 310 are respectively represented by the lines 312 and 314 on FIGs. 3B and 3C. The polarization direction of the polarized material 310, illustrated with lines 314 in FIG. 3B, is represented by the dots in the array region 304 shown in FIG. 3C. As shown by lines 312 and 314 on FIG. 3B, the respective polarization directions of the polarized material 308 and the polarized material 310 are selected so that they are generally orthogonal to each other. The polarized material 308 and the polarized material 310 may be formed from the same material, but disposed with their respective polarization directions oriented generally orthogonal to each other. If the polarization directions of the polarized material 308 and the polarized material 310 are properly selected, the respective materials may act as filters suitable for filtering out radiation that is linearly polarized in a direction generally orthogonal to the polarization direction of the respective materials. As alluded to above, this filtering phenomenon is attributed to the polarized materials used in the present invention absorbing light that has an electric field vector perpendicular to the polarization direction of such materials and does not absorb light, to an appreciable amount, when the electric field vector of the light is parallel to the polarization direction of such materials.

[0027] For instance, linear polarized light having a polarization direction generally parallel to the polarization direction of polarized material 308 will be filtered by polarized material 310. Furthermore, linear polarized light having a polarization direction generally parallel to the polarization direction of the polarized material 310 will be filtered by the polarized material 308. Materials that may be used for the polarized material 308 and polarized material 310 are selected for filtering ultraviolet wavelength light used in photolithography systems. Examples of suitable materials for polarized material 308 and polarized material 310 include inorganic materials such as, for example, calcite, mica, quartz

retardation plates, dichroic sheet polarizers, BK7 (borosilicate glass available from Melles Griot), and UV-grade fused silica. Examples of suitable materials for polarized material 308 and polarized material 310 further include organic materials such as, for example, ferroelectric polymers (in bulk form and as a Langmuir-Blodgett film), polyvinylidene fluoride, and liquid crystal polymers. Suppliers of the above materials include Melles Griot and Oriel instruments. These exemplary materials absorb or block approximately 98 percent of incident light having a polarization direction generally orthogonal to the polarization direction of the polarized material.

[0028] The films of polarized material 308 and polarized material 310 may be formed on reticle 301 by various deposition techniques. Chemical vapor deposition (CVD), physical vapor deposition (PVD), and atomic layer deposition (ALD) are suitable for depositing the films in the particular defined areas that form the peripheral region 302 and the array region 304 of polarized reticle 300. The application of the polarized materials in the peripheral region 302 and the array region 304 may be performed using masking and etching techniques common to photolithographic processing used in the semiconductor fabrication industry. The polarized material 308 and the polarized material 310 may also be applied to reticle 301 in their respective locations by manual application of preformed films of the above mentioned polarized materials having their respective polarization directions oriented in the desired direction. The manual application of the polarized material 308 and the polarized material 310 may be assisted by an operator/technician performing it under a microscope and using a microcaliper to assist in the accurate placement of the polarized materials on reticle 301 in the desired regions. The films of the polarized material 308 and the polarized material 310 may also be a Langmuir-Blodgett type of film. The Langmuir-Blodgett films are monomolecular layers first preformed on a liquid surface and then transferred onto reticle 301.

[0029] Referring to FIG. 4, an exemplary photolithography system 400 using the polarized reticle 300 of the present invention is illustrated. Illumination controller 102 may be controllably coupled to illuminating source 104 for projecting linear polarized light 402. Illumination source 104 may be a laser capable of producing linear polarized light. Illuminating source 104 may also include, for example, a mirror, a lamp, a laser, a light filter, and/or a condenser lens system. The term “light” as used herein is not restricted to

visible light, but may also include any form of radiation energy such as photons, laser beams, or X-rays. Half-wave polarization plate 404 is sized and configured to be inserted in the pathway of linear polarized light 402 using a removable or rotatable chuck (not shown). Half-wave polarization plate 404 may be a half-wave polarization plate formed from mica manufactured by Melles Griot. For example, if the polarization direction of the linear polarized light 402 is polarized in the vertical direction (i.e. perpendicular to the polarized reticle 300 and half-wave polarization plate 404), the half-wave polarization plate 404 oriented with its fast or slow optical axis forty-five degrees to the vertical direction will alter the polarization direction of linear polarized light 402 by ninety degrees upon passing therethrough. Such half-wave polarization plates may be either inserted in the pathway of linear polarized light to change its polarization direction by ninety degrees or the half-wave polarization plate 404 may also be in a fixed positioned in the pathway of linear polarized light 402 and rotated to a specific angle relative to the polarization direction of the linear polarized light 402 to change the polarization direction linear polarized light 402.

[0030] When half-wave polarization plate 404 is configured to be in the pathway of linear polarized light 402, it causes approximately a ninety degree rotation in the polarization direction of linear polarized light 402. Polarized reticle 300, defining a pattern to be projected onto photoresist 110, receives light rays 402 directly from illuminating source 104 or from half-wave polarization plate 404 to produce reticle pattern image 406 representative of a selected portion of the pattern of polarized reticle 300. Optionally, polarized reticle 300 may be secured to a hard or soft pellicle to protect polarized reticle 300 from contaminants. Hard pellicles include, for example, glass or polymer fibers.

[0031] Again with reference to FIG. 4, a projection lens apparatus 108 may receive reticle pattern image 406 from polarized reticle 300. Projection lens apparatus 108 may be, for example, a reduction lens or a combination of lenses and/or mirrors for focusing reticle pattern image 406 onto the surface of photoresist 110 on substrate 112. Typical semiconductor fabrication photolithography involves a four to ten times reduction of the pattern size on polarized reticle 300 for projection onto a target substrate 112. Projection lens apparatus 108 projects reticle pattern image 406 to produce a projected pattern image 408.

[0032] Projected pattern image 408 may then be irradiated onto photoresist layer 110 on substrate 112. Substrate 112 may be a semiconductor substrate such as single crystal silicon, single crystal gallium arsenide, polysilicon, indium phosphide, a layered bulk semiconductor substrate (such as a silicon on insulator (SOI) substrate as exemplified by a silicon on glass (SOG) or silicon on sapphire (SOS) substrate), a glass (for example, soda-lime glass, borosilicate glass, or quartz) useful for forming reticles, or any other suitable material such as those used in forming liquid crystal displays and thin film magnetic heads. Substrate 112 having photoresist 110 disposed thereon may be supported and held in position on a holding device such as a chuck (not shown) which may be part of, or controlled by, a stepper (not shown), as known in the art.

[0033] Again with reference to FIG. 4, the operation of photolithography system 400 used in conjunction with polarized reticle 300 will be more fully understood. Illumination controller 102 initiates illumination source 104 to produce linear polarized light 402. Linear polarized light 402 is selectively polarized in a direction generally parallel to the polarization direction of the polarized material 308 or the polarized material 310. Linear polarized light 402 is also selectively polarized in a direction generally orthogonal to the polarization direction of one of the polarized material 308 or the polarized material 310. Thus, when the polarization direction of linear polarized light 402 is generally parallel to the polarization direction of one of the polarized materials on reticle 301, the light is transmitted through it. Conversely, when the polarization direction of linear polarized light 402 is generally orthogonal to the polarization direction of one of the polarized materials on reticle 301, the light is filtered and does not transmit through to reticle 301. The illumination conditions of the linear polarized light 402 such as, the dose, the depth of focus, incidence angle, among other variables may be optimized for the particular region of the polarized reticle 300 being exposed.

[0034] For example, linear polarized light 402 having a polarization direction generally orthogonal to the polarization direction of polarized material 308 is irradiated upon polarized reticle 300. Linear polarized light 402 is transmitted through the polarized material 310 and, thus, through array region 304 of polarized reticle 300. The light is not transmitted to a substantial extent through polarized material 308. The reticle pattern image 406 of the array region 304 may then be projected by projection lens apparatus 108 to

irradiate photoresist 110 with a projected pattern image 408. A pattern representative of the pattern defined within the array region 304 of polarized reticle 300 is formed on photoresist 110.

[0035] Following formation of the pattern of array region 304 on photoresist 110, the half-wave polarization plate 404 may be moved in the pathway of the linear polarized light 402 or rotated to the required position if the half-wave polarization plate is already in the pathway of the linear polarized light 403. Upon linear polarized light 402 passing through half-wave polarization plate 404, the polarization direction of the exiting light is altered by approximately ninety degrees. Thus, now the polarization direction of the linear polarized light 402 is generally orthogonal to the polarization direction of polarized material 310 and generally parallel to the polarization direction of the polarized material 308. Then, linear polarized light 402 is transmitted through the polarized material 308 and, thus, through peripheral region 302 of polarized reticle 300. The light is not transmitted to a substantial extent through polarized material 310. The reticle pattern image 406 of the peripheral region 302 may then be projected by projection lens apparatus 108 to irradiate photoresist 110 with a projected pattern image 408. A pattern representative of the pattern defined within the peripheral region 302 of polarized reticle 300 is formed on photoresist 110. The above description of the operation of photolithography system 400 is merely an example. Alternatively, the peripheral region 302 may be exposed first, followed by insertion or rotation of the half-wave polarization plate 404, and subsequently the exposing of the array region 304.

[0036] Although the foregoing description contains many specifics, these are not to be construed as limiting the scope of the present invention, but merely as providing certain exemplary embodiments. Similarly, other embodiments of the invention may be devised which do not depart from the spirit or scope of the present invention. The scope of the invention is, therefore, indicated and limited only by the appended claims and their legal equivalents, rather than by the foregoing description. All additions, deletions, and modifications to the invention, as disclosed herein, which fall within the meaning and scope of the claims are encompassed by the present invention.